Research Article
Open Access
CrossMark

Potential for rain water capture in semi-arid urban areas

Abstract

The semi-arid region of Paraiba is devastated by extreme climatic conditions, in which the low index and the irregularity of the rains are factors of great negative impact for the development of the region. We found in rainwater collection systems, an important alternative for the region, which can increase the volume of water available to a municipality, for the same rainfall regime. Therefore, one of the main objectives of the study was to estimate the Potential Volumes of Rainwater Capture (VPC) for the urban area of São João do Cariri. These volumes will be estimated based on the proposed use of the city's impermeable surfaces as rainwater catchment areas for non-potable purposes. Such an estimation is important for the adequate dimensioning of cisterns, in order to guarantee the supply of thenon-potablewater demands of the population during the dry season.

Keywords: semi-arid, rainfall regime, rainwater collection systems

Volume 6 Issue 6 - 2022

Leonardo Vinícius Queiroz de Paiva,[1] Bartolomeu Israel de Souza[2]

[1]Master's student at PRODEMA at the Federal University of Paraíba, Brazil
2Prof. Dr. From PRODEMA at the Federal University of Paraíba, Brazil

Correspondence: Leonardo Vinícius Queiroz de Paiva, Master's student at PRODEMA at the Federal University of Paraíba, Brazil, Tel +5583999917322, Email leoviniciu_@hotmail.com

Received: October 14, 2022 | **Published:** November 28, 2022

Introduction

Water scarcity is a socio-environmental problem faced in different parts of the planet, and it can lead to truly alarming situations in certain places. Water is an essential resource for life, and its lack in regions such as the Brazilian semi-arid region leads to extreme adversities, especially food insecurity. Even though this issue has been tackled since the oldest civilizations, in addition to being widely discussed today, it is still a very real problem, which is often exacerbated by inadequate public policies, interests of the regional elite, in addition to the climatic moment itself. Among the climate elements, rainfall is the one with the greatest spatio-temporal variability, a characteristic that is striking in the semi-arid region of Paraíba, where precipitation is notoriously irregular in terms of both quantity and distribution. A rainfall regime marked by this limiting condition ends up generating water insecurity and, consequently, preventing the expansion of family farming, raising social inequalities and hindering the survival of men in the countryside as a whole.[1] Despite the low rainfall, associated with the spatial and temporal irregularity of the rainfall regime, the potential for using this amount of rainwater in the semi-arid region of Paraíba, and specifically in the Cariri micro-region, is visible. Such use can be satisfactorily achieved through simple social technologies, with emphasis on rainwater storage and harvesting technologies. Gnadlinger[2] considers the adoption of these techniques the expression of a new paradigm, in which the development of the region focuses on the local population, in addition to being in accordance with the principle of sustainable development.

Rainwater harvesting has been commonly performed for centuries, both in urban and rural places, and this ancient practice was primarily intended for domestic use and, to a lesser extent, agricultural use. In modern cities the use of this water has grown gradually, being considered of great help in solving the challenges related to the supply of good quality water to the population. In addition, there is a growing concern about the need for management of the hydrological system, since it is known the negative interference that most urban environments generate in the hydrological cycle.[3] The Brazilian semi-arid region is considered the most humid on the planet, with an average rainfall of 750 mm/year (ranging from 250 to 800 mm/year in the municipalities of the region). In addition, it is the most populous and considered the semi-arid region with the most precarious conditions of survival.[4] Given this reality, the intention of this work is to propose the use of impermeable surfaces in the urban area of the municipality (squares, pavements, streets), as a means of capturing rainwater. Such a resource would flow naturally through the rainwater drainage routes, and at certain points would be directed and stored in cisterns strategically distributed throughout the city, taking into account its topography and the availability of adequate space for the installation of cisterns. Therefore, a study was carried out on the pluviometric regime of the place, in addition to estimating the potential volumes of rainwater capture and the necessary volumes of water and capture areas, ensuring that the cisterns are dimensioned with sufficient volume to meet the demands non-potable water in the city during the dry season.

Theoretical reference

According to Souza[5] the development of a region is directly related to water security, that is, to the availability of water. From this perspective, it can be understood that the drought has a decisive contribution to the low level of development of the northeastern semi-arid region. However, this climatic reality is not alone responsible for the recurring drama that the population of this region suffers. In communion, political, social and economic factors build this worrying situation, the last two factors being aggravated by climatic conditions. Although the Brazilian semi-arid region is the rainiest, its subsoil is largely formed by crystalline rocks, originating predominantly shallow soils, making the formation of permanent rivers difficult, in addition to the fact that the water tends to have high levels of salts. In addition, a striking feature of the Brazilian semi-arid region is the spatiotemporal variability of rainfall, associated with low annual rainfall values, with the occurrence of a large number of consecutive days without rain being common.[6] The Brazilian semi-arid region has always suffered from the occurrence of severe droughts, however, it is also marked by episodes of major floods. Correia[6] reports that there are between 18 and 20 years of drought for every 100 years, however there has been an increase in their frequency since the 20th century. Events of this magnitude have a direct impact on food production, being a limiting factor for the success of agricultural activity in the region. Over the years, we have experienced a change of perspective with regard to combating the effects of drought, ceasing to consider the scarcity of water as the sole reason for the social problems of the Brazilian semi-arid region. The possible coexistence with the semi-arid region can be seen, as long as sustainable practices and relevant public policies are adopted, replacing the unequal fight against drought.[7]

In this context, conti introduces that

Based on the notion of coexistence, the semi-arid region is understood from its potential, culture, knowledge and capabilities of its people and its social actors in the creation and recreation of social processes that generate their autonomy and empowerment. Gradually, this understanding acquires visibility and consistency through the implementation of public policies that respond to the challenges that emerge from the reality of the people. This process characterizes a before and after in the semi-arid region, mainly due to the implementation of policies, programs and projects that integrate sustainable ways, express the exercise of citizenship and translate into quality of life for the population involved.[8] Thus, we are faced with a reality built by a set of factors considered to be distinct, but which are actually interdependent, from the moment that it is intended to achieve an integral improvement in the living conditions of the population of a locality. With this in mind, it is important to apply an interdisciplinary vision, with regard to the construction of projects, whether governmental or not, that can in fact integrate all the necessary knowledge to achieve a real improvement in the population's quality of life. What we experience is a fragmentation of knowledge, which ends up leading to a simplistic or reductionist view of the environmental issues that surround us. On the other hand, the way to reach an approximation of an effective environmental interpretation, which can guide us to a trajectory of possibility of coexistence with the whole that surrounds us, is in the holistic view, in the consideration of the web of highly complex relationships in which we are wrapped. Such a view of knowledge and nature leads us, among other authors, to Morin.

Any methodical activity exists as a function of a paradigm that directs a cognitive praxis. Faced with a simplifying paradigm that consists of isolating, disuniting and juxtaposing, we propose a complex thought that reconnects, articulates, understands and that, in turn, develops its own self-criticism. [...] From the etymological point of view, the word "complexity" is of Latin origin, it comes from complectere, whose root plectere means to braid, to entwine. It refers to the work of building baskets, which consists of intertwining a circle, joining the beginning with the end of small branches. At first glance, complexity is a fabric of heterogeneous elements inseparably associated, which present the paradoxical relationship between the one and the multiple. Complexity is effectively the network of events, actions, interactions, feedbacks, determinations, accidents that constitute our phenomenal world. Thus, complexity presents itself under the disturbing aspect of perplexity, disorder, ambiguity, uncertainty, that is, of everything that is found in the tangle, inextricable.

According to Leff (2011), a whole crisis motivated by the fragmentation of knowledge and environmental degradation, ends up effectively arousing attention in the late 1960s, when the relationship between contemporary problems and the so-called logocentrism of modern science become more evident, as well as, the technological rationality fomenting the economy of the world. With this, the environmental issue starts to emerge, linked to its inherent complexity and to be given the deserved importance to interdisciplinarity, as being the interconnection between various fields of knowledge, which transcends the field of research and teaching in what concerns limitedly to the scientific disciplines and their possible articulations. With regard specifically to this work, interdisciplinarity is evenly distributed, from its scope to the opportunity that is intended to be built to achieve the proposed objectives. The work intends to bring a social benefit from an ancestral knowledge linked to social technologies developed by the oldest civilizations, and by their reproductions in contemporary times. This work bias links it to several social disciplines, which interact harmoniously with technical requirements in engineering, statistics, exact and natural sciences, among others, in order to make possible the implementation of the proposed methodology.

Scientific studies for the region were emerging and deepening, in an attempt to mitigate the damage to the economy and the very life of the population. As more critical eyes were drawn to the problem of drought, social problems as impacting for the people of the semiarid region as exclusively climatic issues came to the fore. The concentration of wealth and political power came to be seen as one of the great factors that established the condition of misery for the vast majority of the population. The adoption of inefficient government measures, in the context of combating drought, is until today, among the main causes of this current failed reality. In this context, of extreme climatic conditions, in which adversities are maximized by man's relations with the environment, it is essential to adopt public policies that favor coexistence with the region. Coexistence policies will be positive, as long as they enable the development of a harmonious relationship between the population and the space in which they live. Among the public policies, the social technologies for capturing and storing rainwater deserve to be highlighted, which are of great value to the population in periods of drought, whether for human consumption, animal watering, food production, among other purposes.

Within this, in 1999 the Articulation in the Brazilian Semi-Arid (ASA) was created, with the purpose of stimulating sustainable policies for coexistence with the semi-arid region. ASA argues that one of the main alternatives to adapt to the environmental conditions of the region lies in the adequate storage of rainwater, both from a productive and economic point of view.[10] Such thinking agrees with Gnadlinger,[2] who considered the capture and storage of rainwater "expression of a new paradigm in regional development planning, centered on the local population, being economically viable, socially fair and ecologically sustainable" The Training and Social Mobilization Program for Coexistence with the Semi-arid Region - One Million Rural Cisterns (P1MC), was the result of the Third Session of the United Nations Conference of the Parties to the Convention to Combat Desertification (COP 3), in 1999 in the capital of Pernambuco, where sixty-one non-governmental organizations formed the Articulation of the Semi-Arid (ASA). The program aims to promote coexistence with the drought, ensuring access to equipment for capturing and storing rainwater for one million families. At P1MC, 16,000 liter cisterns are built, in addition to expanding and repairing the roofs of houses that need them. Such care is taken because houses are found in the region with inappropriate roofing for the capture, as is the case of asbestos tiles.

In addition to the P1MC, there is the Uma Terra Duas Águas Program (P1+2), which aims to provide the rural population with access to land and water, as well as its sustainable management, the promotion of food and nutritional security and the generation of jobs and income for families in the semiarid region. P1+2 works with other technologies in addition to plate cisterns, such as sidewalk and runoff cisterns, underground dams and stone tanks.[10] All of these social rainwater harvesting technologies mentioned above can play a decisive role in the economic and social development of the semi-arid region, as they can promote water and food security, in addition to boosting agriculture. However, according to Santos[11] the irregularity of rainfall in the region, associated with the inefficiency of government policies, especially in relation to the planning and management of available water resources, can lead to the partial collapse of the rural productive system, notably to agricultural activities. Agriculture and Livestock; difficulties in the supply of water and foodstuffs for the population and the increase in unemployment, culminating in impoverishment and forced migration of the population to the cities.

With regard to urban areas, some of the main hydrological changes are related to the reduction of water infiltration in the soil, as a result of the paving of streets, the construction of buildings and the compaction of the exposed soil. As some of the impacts of this reality, we have the reduction of the water level in the water tables, increased risk of flooding during rainfall peaks and increased transport of pollutants and sediments in urban areas.[12,13] Issues such as those mentioned, along with population growth and climate change, affect the availability of water resources, making it essential to take measures to mitigate the impacts and meet the city's water demand. Urban occupation in Brazil accumulates several cases of adoption of a posture that nurtured the emergence of adverse impacts, both in social, environmental and economic aspects. We can cite the occurrence of irregular occupation of swampy areas, which led to the drying up of swampy areas, filling up areas subject to flooding and straightening rivers. We also have the practice of grounding watercourses, to favor civil construction, with the "creation" of land for commercialization, which generates irreversible consequences. Christofidis et al.[14] clearly expose in their words the impact generated by this type of posture, which was widely adopted in the period of intense urbanization in the country.

In this phase, in which there was intense urbanization in Brazil, the rivers became canalizations and/or gave way to vehicle traffic routes: that is, the rivers became streets; and the reaction to this is that the streets have a high possibility of becoming rivers in times of heavy rainfall.[14] An important factor to be concerned about is the quality of rainwater, since during the occurrence of precipitation rainwater can carry large amounts of pollutants in urban areas. In these periods, substances that have accumulated on the roofs of buildings, on the streets and on other surfaces, are leached and transported to the rainwater drainage system, eventually ending up in adjacent water bodies.[15] Therefore, the problem of rainwater quality lies in the transport of pollutants existing on surfaces, in which the first flush (first flush) after a period without precipitation is the one that contains the highest level of contaminants, as this is where they are concentrated, with subsequent discharges having a considerably lower pollutant load. Thus, according to Schueler.[16]

The wide dispersion of rainwater can spread pollutants over large areas, affecting both surface and groundwater. Depending on the amount transported, and the pollutants to which it is subjected, this source of pollution may eventually cause worrying implications in the surrounding areas, and may interfere with ecosystems and even human health.[17] According to Vivacqua[18] some factors contribute to the variation in the quality of rainwater, among which the main ones can be cited: the frequency of cleaning of the city, as well as the education of the population, in the sense of not discarding waste on the streets; intensity, temporal and spatial distribution of precipitation; time of year and type of use of the urban area. Rainwater harvesting has been commonly carried out for centuries, both in urban and rural areas, and this ancient practice had as its main purpose domestic use and, to a lesser extent, agricultural use. In modern cities, the use of this water has gradually grown, being considered of great help in solving the challenges related to the supply of good quality water for the population. In addition, there is a growing concern about the need for management of the hydrological system, since it is known the negative interference that most urban environments generate in the hydrological cycle.[3]

For some authors, such as Gurung and Sharma[19] rainwater harvesting becomes important, in the sense of reducing dependence on the conventional water supply system, as well as reducing costs related to maintenance, operation and infrastructure. structure of this. In addition, it contributes significantly to reducing the volume of water that flows into the urban environment and can be used for non-potable purposes without the need for complex chemical or biological treatments. Thus, in order to avoid such consequences, it is essential to take planning measures that avoid the use of social technologies in an equivocal or inefficient way. In relation to rainwater harvesting, it is essential to establish a rainfall regime, in order to later adequately estimate the potential volume of rainwater harvesting, the catchment area and the necessary volume of water. These are fundamental requirements to avoid under or oversizing the volumes to be stored.[1]

Materials and methods

As a priority, the rainfall regime was established through descriptive statistical analysis. For this analysis, rainfall data were needed, which are made available by the Executive Agency for Water Management of the State of Paraíba (AESA). The rainfall series was ordered according to the chronological sequence monthly (sum of daily values) and annual (sum of monthly totals). Then, based on climatological statistical criteria, measures of central tendency (mean and median) and dispersion (amplitude and standard deviation) were established. In addition, levels of 25, 50 and 75% probability were chosen, which correspond to the chance of occurrence of one, two or three years for every four years, respectively. With the annual rainfall values and adopting values for catchment areas (AC), the potential volumes of rainwater catchment (VPC, in m³) will be estimated. For each area, the VPC's will be established from equation 1, according to seven rainfall scenarios: average, median, wettest year, driest year and the three levels of probability of rain. Equation 1- Potential volume of rainwater harvesting

$$VPC = \text{rain (mm)} \times AC\ (m^2) \times Ce \quad (1)$$

Ce= flow coefficient (dimensionless)

The surface runoff coefficient (Ce) was adopted according to the average of the Runnof coefficient for different types of surface and areas occupied in different ways, as can be seen in the two following Table 1, 2.

Table 1 Mean values of Runnof coefficients

Surface type	Runoff coefficient (C)
Asphalt pavement	0,95
Concret pavement	0,95
Brick pavement	0,85
Stone pavement	0,75
Green roof < 10 cm	0,50
Green roof > 50 cm	0,10

Source: LEED existing buildings, 2009.

The volume of water needed (VNEC, in L) and the consequent necessary catchment area (ACN, in m²) for the accumulation of such volume will be calculated through equations 2 and 3, respectively.

Equation 2- Volume of water needed

$$VNEC\ (L) = n \times c \times p$$

Citation: de Paiva LVQ, de Souza BI. Potential for rain water capture in semi-arid urban areas. *Int J Hydro.* 2022;6(6):236–241.
DOI: 10.15406/ijh.2022.06.00331

Where: n = total number of people to be served (unit.)

c = daily per capita consumption (in L)

p = period without rain (days)

Once the values of volumes of water required are obtained, it will be possible to calculate the required catchment area (ACN):

Equation 3- Required catchment area

$$ACN=\frac{VNEC}{Ce\times P}$$

P = Annual rainfall for each rainfall scenario

Table 2 Runoff coefficient values for different areas

Surface characteristic	Runoff coefficient (C)
Commercial area	
Central	0,70 – 0,95
neighborhoods	0,50 – 0,70
Residential area	
Isolated residences	0,30 – 0,50
Area with buildings	0,50 – 0,70
Industrial area	
light industries	0,50 – 0,80
heavy industries	0,60 – 0,90

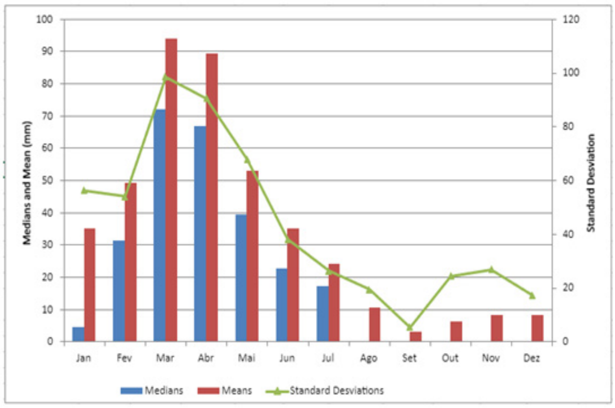
Source: ASCE/WEF (Chow, 1962)

The volumes of water needed and the necessary catchment areas will be calculated for several possible uses that could be given to the resource, as well as for more than one consumption value. In addition, as mentioned earlier, a study was carried out on the flow of rainwater runoff in the city, in order to propose strategic storage points for this resource. For this, the Global Mapper 20 software was used to generate the contours of the location, in addition to the observation of satellite images and photos of the city streets, through Google Earth Pro and the Street View tool.

Results

São João do Cariri Pluvial Regime

The graph below shows the averages, medians and standard deviation of monthly rainfall in the municipality. There is a high dispersion, with the Standard Deviation being greater than the averages in at least five months and then the medians in seven months. This fact shows us the irregularity of the monthly rainfall for the locality Graph 1. Still in relation to the irregularity of the rains, besides the bad distribution of them during the months of the year, it is noticed that the annual variability reaches a significant amplitude (1,227 mm), resulting from a wettest year with 1,352 mm and a less rainy year with 125 mm. In addition, the arithmetic mean values are greater than the respective medians. Such characteristics indicate that the asymmetry coefficient is positive. In view of this, despite the mean being the measure of central tendency usually used, in this case, the median is the most likely value to occur, which is in agreement with studies carried out by Silva and Almeida;[20] Almeida and Oliveira[21] and Almeida and Gomes[22] to other locations in the Cariri region of Paraíba. It can also be observed that despite the great variability of rainfall distribution between years, there is a certain pattern with regard to the driest months, which are between September and December. While the rainy season begins between February-March and ends between May-June, concentrating around 65% of the total annual rainfall (232 mm), with March and April being the wettest months with 39% (139 mm).

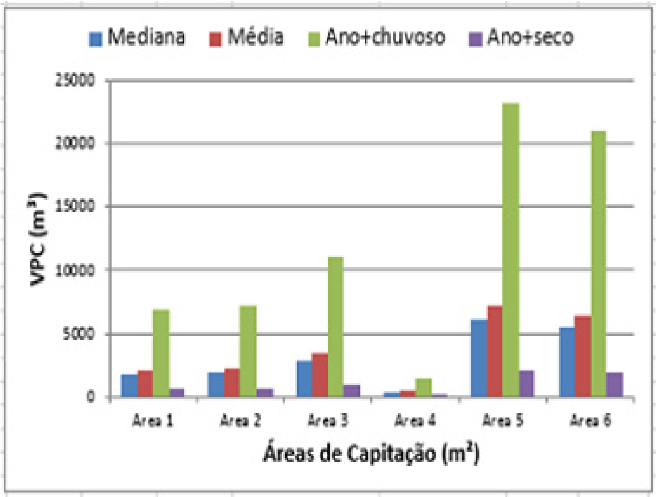


Graph 1 Means, medians and standard desviation of the monthly rainfall series in the municipality of São João do Cariri.

Source: Prepared by the author.

Potential volume of rainwater collection for São João do Cariri

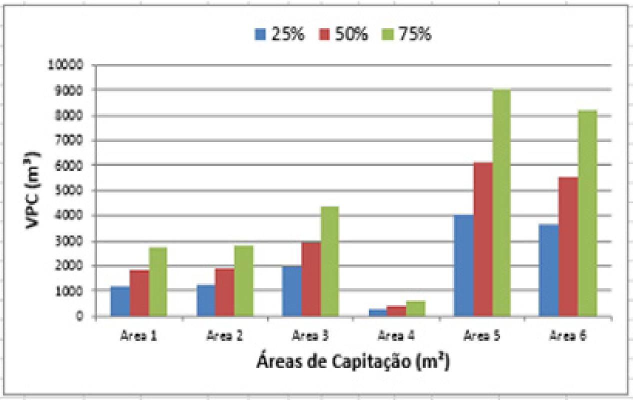
In order to work with estimates of potential volumes of rainwater harvesting (VPC), it is essential, a priori, to establish a monthly and annual rainfall regime, based on the historical rainfall series of the locality under study. The VPC's were established based on the rainfall regime, surface runoff coefficient and the catchment area, which in this case corresponds to the areas of streets, stormwater runoffs and city squares. Such catchments were defined with the help of Google Earth Pro and Global Mapper 20, as can be seen in the satellite Figure 1 below. It was proposed to subdivide the urban area of the city into six catchment areas, with seven potential storage points for the captured water. The subdivision was made based on the analysis of the flow of the resource through the streets of the city. For this, the contours of the city were taken into account and the slope of each street was observed separately, with the help of the Google Street View tool, from Google Earth Pro. The potential volume of abstraction was established for each of the six areas, according to seven different rainfall scenarios, as can be seen in graph 2 and 3. However, as mentioned earlier, the scenario that best represents the reality of the region in which the municipality is inserted, is the median.



Graph 2 Potential volumes of rainwater harvesting (VPC) for the different catchment areas and four scenarios of rain occurrence.

Source: Prepared by the author

Citation: de Paiva LVQ, de Souza BI. Potential for rain water capture in semi-arid urban areas. *Int J Hydro.* 2022;6(6):236–241.
DOI: 10.15406/ijh.2022.06.00331



Graph 3 Potential volumes of rainwater harvesting (VPC) for different catchment areas and three scenarios of occurrence of rain.

Source: Prepared by the author

Figure 1 Rainwater catchment areas in São João do Cariri.

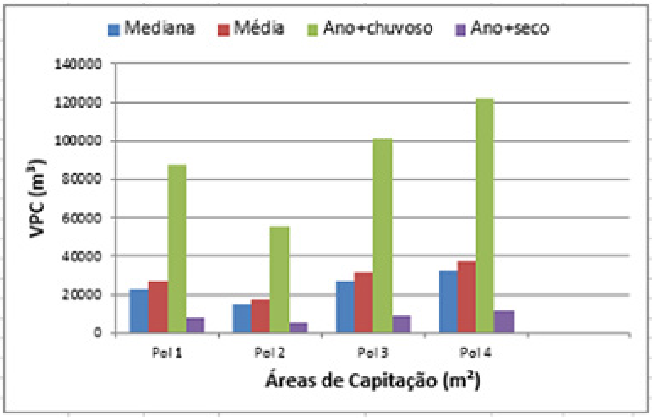
Source: Google Earthe Pro; adapted by the author.

By observing the median of each area, we see that encouraging annual values were found for the potential volumes of rainwater harvesting, area 5 having the largest of them (6,098 m³/year) and area 4 with the smallest (394 m³ /year). Even if it were considered the driest year, as a representative parameter of the rainfall reality of the municipality, we would have for the largest areas, which are area 5 and 6, approximate values of 2,140 m³ and 1,950 m³, respectively, and an annual total of 6,545 m³ considering all six catchment areas. That is, a considerable amount of water, which could be of great value for various non-potable purposes in the city. Taking into account that most of the residences in the municipality do not have cisterns, therefore, a part of the water that precipitates on their roofs ends up being directed to the rainwater drainage routes (channels), the calculation of the VPC's was also carried out with the addition of the area of these houses as a catchment area. For this, the city was divided into 4 polygons, according to the resource flow, as can be seen in the following Figure 2.

For this scenario, as expected, much higher values were found than for the first hypothesis, with regard to this potential for rainwater harvesting. We would have approximate annual values of 22,945 m³, 14,670 m³, 25,700 m³, 32,163 m³, for polygons 1, 2, 3 and 4, respectively. Such values match the medians of rainfall, if the averages were the values closer to the reality of the locality, as in other regions, these values would be even higher, as can be seen in the following graph 4, 5.[23–26]

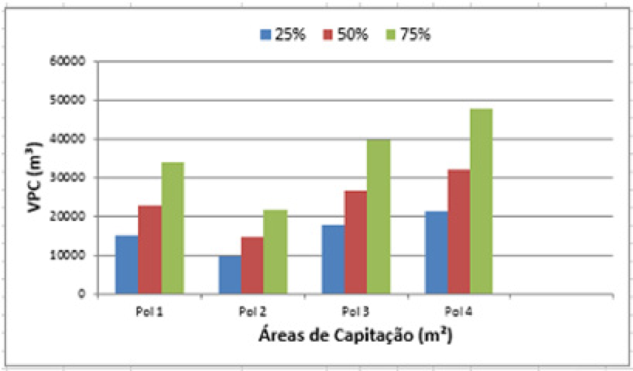
Figure 2 Second hypothesis of rainwater catchment areas in São João do Cariri.

Source: Google Earth Pro; adapted by the author



Graph 4 Potential volumes of rainwater abstraction (VPC) for different abstraction polygons and four scenarios of occurrence of rain.

Source: prepared by the author.



Graph 5 Potential volumes of rainwater abstraction (VPC) for different abstraction polygons and three scenarios of occurrence of rain.

Source: prepared by the author.

Conclusion

The distribution of rainfall is extremely irregular, with abrupt differences between the rainfall rates of the short rainy season and the dry season. The asymmetry of the rainfall regime is also confirmed by the variability of rainfall rates from each month, from one year to another. In addition, the standard deviation exceeds the averages themselves in some months, which represents the high dispersion in relation to it. This tells us that the median is the measure of central

Citation: de Paiva LVQ, de Souza BI. Potential for rain water capture in semi-arid urban areas. *Int J Hydro.* 2022;6(6):236‒241.
DOI: 10.15406/ijh.2022.06.00331

tendency most likely to occur. The months of March and April are the months with the most rainfall, with medians above 60 mm, and equivalent to 39% of the total annual rainfall. Even with severe weather conditions for the region, it was found a high potential for rainwater harvesting for the locality. It appears that the capture and storage of this resource can be of great value to meet the water needs of the city for non-potable purposes in its entirety. Therefore, this strategy proves to be an excellent helper in living with the drought.

The volumes of the cisterns must be sized according to the volume of water needed and the catchment area available for each case. The rainfall regime and the consequent potential for rainwater harvesting (VPC) must be considered when sizing the cisterns, to avoid under- or over-sizing. The definition of the rainfall regime and the VPC's of the municipality of São João do Cariri, may have value for governmental programs or other scope, with regard to the efficient dimensioning of the cisterns.

Acknowledgments

None.

Conflicts of interest

The author declares there is no conflict of interest.

References

1. Almeida HA de, FARIAS MP. *Potential for rainwater harvesting as an alternative for the development of the driest localities in the Cariri micro-region of Paraíba*. In: capture, management and use of rainwater. Campina Grande, PB; INSA, chapter 18, 2015. p. 373–386.
2. Gnadlinger J. *The contribution of rainwater harvesting to the sustainable development of the Brazilian semiarid region – a people-focused approach*. In: Brazilian Rainwater Collection Symposium in the Semi-Arid Region, 3, 2001. Campina Grande-PB. Electronic Annals. Campina Grande, 2001.
3. Buhaug H, Urdal H. An urbanization bomb? Population growth and social disorder in cities. *Global Environmental Change*. 2020;23(1):1–10.
4. Malvezzi R. *Semi-Árido: uma visão holística*. Brasília: CONFEA, 2020.
5. Souza JG de. *The Brazilian northeast: an experience of regional development*. 1st ed. Fortaleza: Banco do Nordeste. 1979.
6. Correia RC, Kiill LHP, Moura MSB, et al. *A região semiárida brasileira. Produção de caprinos e ovinos no Semiárido*. In: Voltolini TV, editor. Cap. 1, Petrolina: Embrapa Semiárido, 2018. p. 21–48.
7. Pontes ETM, Machado TA. *Programa um milhão de cisternas rurais no nordeste brasileiro: políticas públicas, desenvolvimento sustentável e convivência com o semi-árido*. XIX ENGA, São Paulo, 2009. p. 1–25.
8. Conti IL, Schroeder EO. Estratégias de Convivência com o Semiárido Brasileiro: Textos e Artigos de Alunos(as) Participantes. Fundação de Apoio da Universidade Federal do Rio Grande do Sul – FAURGS /REDEgenteSAN / Instituto Brasileiro de Desenvolvimento e Sustentabilidade – IABS / Agência Espanhola de Cooperação Internacional para o Desenvolvimento – AECID / Ministério do Desenvolvimento Social e Combate à Fome - MDS / Editora IABS, Brasília-DF, Brasil. 2016.
9. Morin E. *Educating in the planetary age: Complex thinking as a method of learning through human error and uncertainty*. São Paulo: Cortez; Brasília, DF: UNESCO, 2003b. p. 1–105.
10. Alves AP. Coexistence Strategies with the Brazilian Semiarid Region. Article: Living with the Semiarid Region. Support Foundation of the Federal University of Rio Grande do Sul – FAURGS /REDEgenteSAN / Brazilian Institute for Development and Sustainability – IABS / Spanish Agency for International Development Cooperation – AECID / Ministry of Social Development and Fight against Hunger - MDS / IABS Publishing, Brasília-DF, Brazil. 2013. p. 1–212.
11. Santos MJ, Araujo LE, Oliveira EM, et al. Drought, precipitation and rainwater harvesting in the semi-arid region. *Environmental Engineering - Espírito Santo do Pinhal*. 2009;6(1):055–073.
12. Ghimire SR, Johnston JM, Ingwersen WW, et al. Life cycle assessment of domestic and agricultural rainwater harvesting systems. *Environmental Science & Technology*. 2014;48(7):4069–4077.
13. Niemczynowicz J. Urban hydrology and water management – present and future challenges. *Urban Water*. 1999;1(1):1–14.
14. Christofidis D, Assumpção RSFV, Kligerman DC. A evolução histórica da drenagem urbana: da drenagem tradicional à sintonia com a natureza. Saúde Debate. *Rio de Janeiro*. 2019;43(Special issue 3):94–108.
15. Santos J. Gestão de águas pluviais urbanas: mudança do paradigma nos sistemas públicos de drenagem. *Dissertação submetida para satisfação parcial dos requisitos do grau de Mestre em Engenharia do Ambiente*. Faculdade de Engenharia. Universidade do Porto. 2010. p. 166.
16. Schueler T. *Controlling urban runoff: a practical manual for planning and designing urban BMP*. Washington, DC: Metropolitan Washington Council of Governments, 1987.
17. Santos MJJ. *Caracterização e monitorização de secas.* INAG – DSRH – Instituto da Água – Direção de Serviços de Recursos Hídricos. Dezembro, 2021. p. 26.
18. Vivacqua MCR. *Urban Surface Runoff Water Quality – Review for Local Use*. Dissertation – Polytechnic School of the University of São Paulo. Department of Hydraulic and Sanitary Engineering, São Paulo, 2005. p. 185.
19. Gurung TR, Sharma A. Communal rainwater tank systems design and economies of scale. *J Clean Product*. 2014;67:26–36.
20. Almeida HA de, Oliveira GC de S. *Potential for rainwater harvesting in Catolé de Casinhas, PE*. In: Brazilian symposium on rainwater harvesting and management, 7. Caruaru, PE. 2009.
21. Almeida HA de, Gomes AVM. *Potential for rainwater harvesting: alternative water supply in public schools in Cuité, PB*. In: Brazilian Congress of Agrometereology, 17, Guarapari, ES, Anais, Guarapari. 2011.
22. Silva L, Almeida HA de. *Estimation of the potential for rainwater harvesting in Quixadá, CE*. In: Brazilian symposium on rainwater harvesting and management, 7. Caruaru, PE. 2009.
23. CHOW VT. *Hidrologic Determination of Waterway Areas for the Design of Drainage Structures in Small Drainage Basins*. University of Illinois. Engineering Experiment Station Bulletin, no. 462, 1962. p. 104.
24. Farias MP. *Potential for rainwater harvesting as an alternative for the development of the driest locations in the Cariri micro-region of Paraíba*. Dissertation (Master in Regional Development) - State University of Paraíba, Campina Grande. 2015. p. 87.
25. Silva RMA. Between Combating Drought and Living with the Semi-Arid Region: public policies and paradigmatic transition. Economic Magazine of the Northeast, Fortaleza. 2007;38(3):466–485.
26. Santos J. *Urban rainwater management: paradigm change in public drainage systems*. Dissertation submitted for partial satisfaction of the requirements of the Master's degree in Environmental Engineering. Engineering College. University of Porto. 2010. p. 166.